The importance of vernacular strategies for a climate responsive building design

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ABSTRACT: In the evolution of vernacular buildings, different strategies have been developed for their adaptation to the surrounding environment. The climate-responsive strategies implemented in vernacular architecture from different regions have the potential for being further developed and could be adapted in answer to contemporary needs. Therefore, based on the need of designing buildings adapted to a specific climate and territory, it is pertinent to study vernacular buildings in order to develop and integrate their design strategies in the up-to-date construction context, contributing to its sustainability. The aim of the paper is to address the correlation between Portuguese vernacular architecture and the different types of climate of the country, highlighting the advantages of a climate responsive building design. Based on several surveys on Portuguese popular architecture, this research work classified and identified the main bioclimatic strategies, mapping and relating them to their specific climate. The results of the study can be used to make a proposal for the retrofitting of vernacular constructions with bioclimatic strategies and to adapt these strategies to new buildings.

Keywords *Vernacular Architecture, Bioclimatic, Solar Passive, Sustainable Building.*

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1. INTRODUCTION

After a period of a construction context based on industrial materials and relying mainly on mechanical systems to provide healthy and comfortable conditions for occupants, the rise of an environmental awareness has started to change the sector towards another paradigm. Thus, nowadays, topics such as comfort, energy and environmental impacts are inseparable from building design. The definition of ambitious targets on buildings energy performance, as the defined by the European Union (EPBD 2010), implies giving relevance to passive strategies that take advantage of available endogenous resources in order to reduce consumption and the dependency on non-renewable energy.

On the topic of passive strategies, vernacular architecture is a type of construction that should be studied, since it is characterized by having an intrinsic relation with local conditions. Thus, through generations across the world, diverse vernacular building techniques and forms have been developed and improved in order to better respond to different climate constraints (Lau et al. 2007; Singh et al. 2009). According to several authors, vernacular architecture could contribute towards reducing waste and energy consumption through the use of passive solar design, traditional techniques, and local materials, which were developed in accordance with a specific territory and climate (Fernandes et al. 2013; Kimura 1994; Singh et al. 2011). The relevance of vernacular features is still valid today being now the basis of sustainable building design (Cañas & Martín 2004; Cardinale et al. 2013).

Portugal is a diverse territory, there are many different manifestations of vernacular constructions and, consequently, different strategies have been developed for their adaptation to the surrounding environment. From north to south, and from the interior to the coast, buildings change in order to accommodate different strategies that serve different ways of living in specific territories. Therefore, based on the need of designing buildings adapted to a specific climate and territory, it is worthy to study Portuguese vernacular buildings in order to develop and integrate their design strategies in the up-to-date construction context.

The aim of the paper is to address the correlation between Portuguese vernacular architecture and the different types of climate of the country, highlighting the advantages of taking into consideration these strategies on a climate responsive building design. The results of the study can be used to make a proposal for the retrofitting of vernacular constructions with bioclimatic strategies and to adapt these strategies to new buildings.

2. METHODOLOGY

The research methodology of this study is based on case studies, using a deductive approach and qualitative analysis for climatic-responsive strategies used in Portuguese vernacular architecture. The data on vernacular strategies was collected from the main surveys on Portuguese popular architecture (AAVV 1988; Oliveira & Galhano 1992). This paper focuses on some case studies located along the mainland Portuguese territory. To relate the use of certain vernacular strategies to specific local climate conditions, examples of different strategies were chosen and mapped. The comparative analysis was established overlapping the strategies points on different climate maps from the Iberian Climate Atlas

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(AEMET & IM 2011). The graphical analysis allowed understanding the relation between strategies purpose and the surrounding climate.

3. CLIMATE AND GEOGRAPHY IN MAINLAND PORTUGAL

Mainland Portugal is located between latitudes 37°N and 42°N in the transitional region between the sub-tropical anticyclone zone and sub-polar depression zone. Besides latitude, the most important features affecting the climate of the territory are orography and the influence of the Atlantic Ocean (Santos et al. 2002). With regard to geographic relief, the highest peaks rise to a height of 1000–1500 m, except for the Estrela Mountains, which highest point is just below 2000 m. Even though it is a small country, Portugal is a territory of contrasts. In spite of the fact that the variation in climate factors is rather small, it is sufficient to justify significant variations in air temperature and rainfall (Santos et al. 2002).

The mainland has a temperate climate – Type C, according to Köppen climate classification (AEMET & IM 2011). The territory is divided into two sub-types of climate: i) The northern part and almost all of the west coast have a climate sub-type Csb, characterised by rainy winters and hot and dry summers. Annual average mean temperature for the majority of this zone is of 15ºC, being of 10ºC in the highest points. The highest values for annual average rainfall are above 2200 mm in the mountainous areas of north-eastern Portugal (Serra do Gerês) (AEMET & IM 2011); ii) The inland southern Portugal has a Mediterranean climate, sub-type Csa, hot and dry during summer. In summer, the mean values for maximum air temperature vary between 32 and 35 °C, reaching sometimes maximum temperatures of 40 °C or 45 °C, being July and August being the hottest months. The annual average rainfall is below 500 mm, and July is the driest month (below 5 mm) (AEMET & IM 2011).

4. BIOCLIMATIC STRATEGIES IN PORTUGUESE VERNACULAR ARCHITECTURE

Vernacular architecture is strongly influenced by its geographical location. Due to the close relation with local conditions, vernacular buildings have different characteristics from region to region. From all the geographical constraints, one of the most relevant is undoubtedly the climate. The diversity of the Portuguese territory promoted a profuse variety of vernacular architecture types. Nonetheless, in general, it can be stated that the northern part has harsher winter conditions, milder summers and higher annual average rainfall, while the southern part is the opposite, with mild winter, harsh summer conditions and lower values for rainfall (Fernandes, Pimenta, et al. 2015). To suit these climatic conditions, Portuguese vernacular architecture developed specific mitigation/adaptation strategies, as shown below.

4.1 Promotion of solar heat gains

From north to south people knew the importance of taking advantage of a good solar exposure of their buildings. Nevertheless, vernacular strategies to promote solar heat gains are more visible in the northern part of the country, as shown in Figure 1. The main reason for this is that winter is the most demanding season in the region. Therefore,

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considering that the main energy source to heat these buildings was wood, it is easy to understand that all the free heat from the sun is welcome.

These concerns are visible since the urban settlement, frequently implanted in valleys and on south-facing slopes, seeking simultaneously to maximise solar gains and protection from the wind. At the building's scale, the most widespread strategy is the correct solar orientation, with the main rooms facing the south quadrant. However, the strategy that takes more advantage of solar radiation is the glazed balcony. The glazed-balconies are a feature of the architectonic identity of the northern interior part of the country (Fig. 1b). The balconies are usually facing between south and west so that they can capture in winter the most intense radiation during the higher number of hours of sunshine while affording the best shelter from the prevailing winds (AAVV 1988). In a sunny winter day, the use of this strategy allows to considerably increase indoor air temperature, reducing energy demand for heating (Fernandes, Pimenta, et al. 2015).

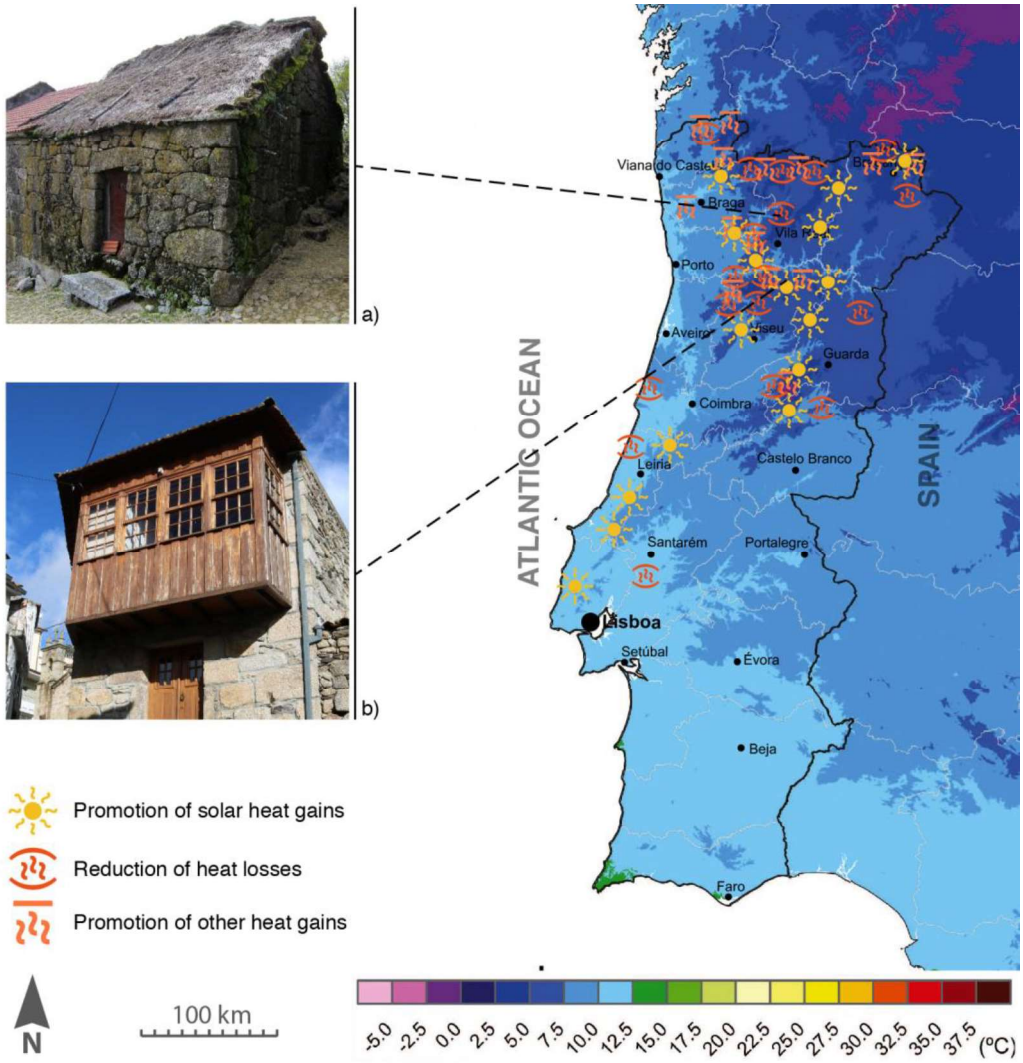

Figure 1. Map of mean air temperature during the winter season in Portugal, showing the points where strategies for promoting heat gains and reducing heat losses are placed. a) Thatched construction; b) glazed-balcony building. Map adapted from (AEMET & IM 2011).

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4.2 Reduction of heat losses / Promotion of other heat gains

In addition to the previous strategy, buildings usually also used other strategies to face cold winters such as reducing indoor heat losses and promoting other heat gains. As seen before, these strategies are also more concentrated in the northern part, being concomitant in many cases.

To reduce indoor heat losses, buildings in mountainous areas had commonly thatched roofs (Fig. 1a). This coating ensures simultaneous protection against rain and some thermal insulation. The straw used for thatching was a waste product from the cultivation of rye, a cereal crop more present in mountainous areas. Additionally, such constructions also have a limited number of windows to avoid heat losses, usually very small, and a low ceiling, which allows to quickly warm up the indoor air.

This concern is also evident in the functional arrangement of the indoor spaces. For example, bedrooms rarely have windows to the exterior and are located next to the kitchen, taking advantage of the heat from the fireplace. In this region, it was also common for cattle to be stabled on the ground floor of the dwelling in order to take advantage of the animals' body heat.

4.3 Passive cooling / minimise heat gains

In opposition to the previous strategies, passive cooling strategies are more concentrated in the south of the country, as shown in Figure 2. The intense summer heat in the south has forced vernacular buildings to develop strategies to minimise heat gains and to promote cooling (Fig. 2). With this purpose, several techniques were developed, such as: reducing the size of windows and doors; the use of high thermal inertia building systems; the use of light colours in order to reflect solar radiation; overnight cooling through natural ventilation; and the use of patios (courtyards).

By minimising the size and number of openings in the envelope, the amount of incident radiation that passes through windows is reduced. The use of small windows also allows that the opening in the wall to act as a shading system.

The use of light colours for the building envelope, mainly whitewashed surfaces (Fig. 2b), reduces heat gains by acting as a radiation reflector, reflecting about 90% of the incident radiation (Oliveira & Galhano 1992; Koch-Nielsen 2002).

From these strategies, the heavy walls made of rammed earth should be highlighted. It is the most widespread vernacular construction technique in the Alentejo region (AAVV 1988). The heavy mass that characterizes earthen constructions allows them to respond appropriately to the hot summer of Alentejo (the major area of all the southern part of Portugal). The good heat storage capacity of rammed-earth walls dampens the outdoor thermal wave keeping indoor temperature and relative humidity stable (Fernandes, Pimenta, et al. 2015; Martín et al. 2010).

The overnight cooling through natural ventilation is particularly useful in hot climates to remove the thermal loads stored during the day. This strategy is promoted in the buildings through the use of small ventilation openings above windows (Fig. 2c) or grid screens similar to the *mashrabiya*. These small openings foster air circulation in the building generating a cooling effect without compromising safety and privacy. This

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strategy involves occupant's action and it is important to ensure thermal comfort conditions throughout the day.

The courtyard (*patio*) is very common in urban contexts and has revealed to have a large influence on the creation of a microclimate near to the building (Fig. 1a). The presence of vegetation and fountains in the *patio* is useful to cool the air through evapotranspiration and water evaporation, respectively. A recent study has demonstrated that during a summer period air temperature in the *patio* remained lower than those recorded for the city centre, with a maximum difference of around 9°C during heat peaks (Fernandes, Mateus, et al. 2015).

The combination of all these strategies allows to achieve indoor thermal comfort conditions during summer season only by passive means, as demonstrated in recent studies (Fernandes, Mateus, et al. 2015; Fernandes, Pimenta, et al. 2015)

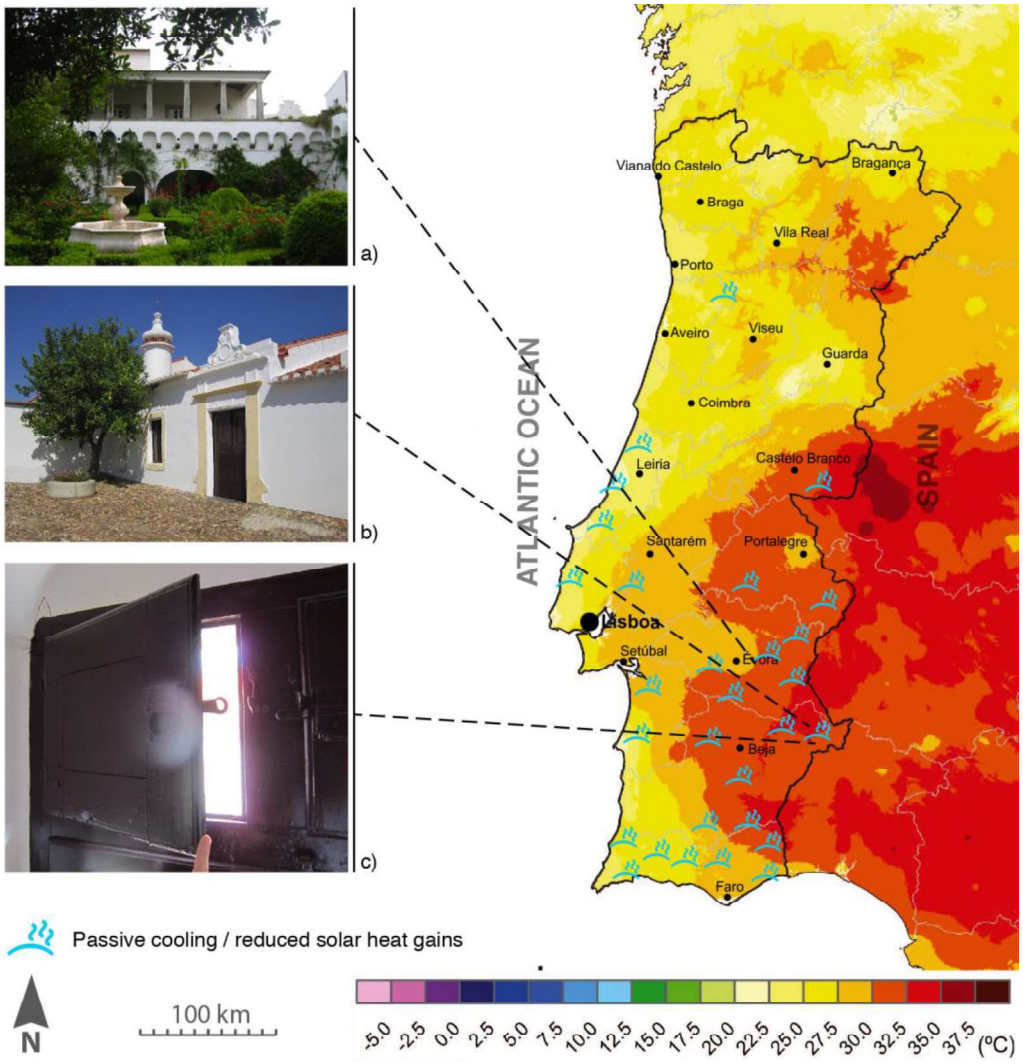

Figure 2. Map of average maximum air temperature during summer season in Portugal, showing the points where strategies for reducing heat gains and promoting passive cooling are placed. a) building with a courtyard (*patio*); b) whitewashed rammed-earth building; c) ventilation window. Map adapted from (AEMET & IM 2011).

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4.4 Rainwater harvesting

In Portuguese vernacular architecture, there are multiple examples of rainwater harvesting and use, either for domestic consumption and agriculture purposes. Most of the examples are located in areas where water resources are scarce or difficult to access, as shown in Figure 3. The abundance of water in some regions of the country, as the northwest, can justify the absence of examples (Fig. 3). However, this is not always true, as it will be explained later. To minimize the lack of water, people developed simple harvesting and water storage systems necessary for their subsistence. In addition to its function, it must be emphasized the architectural integration of these systems.

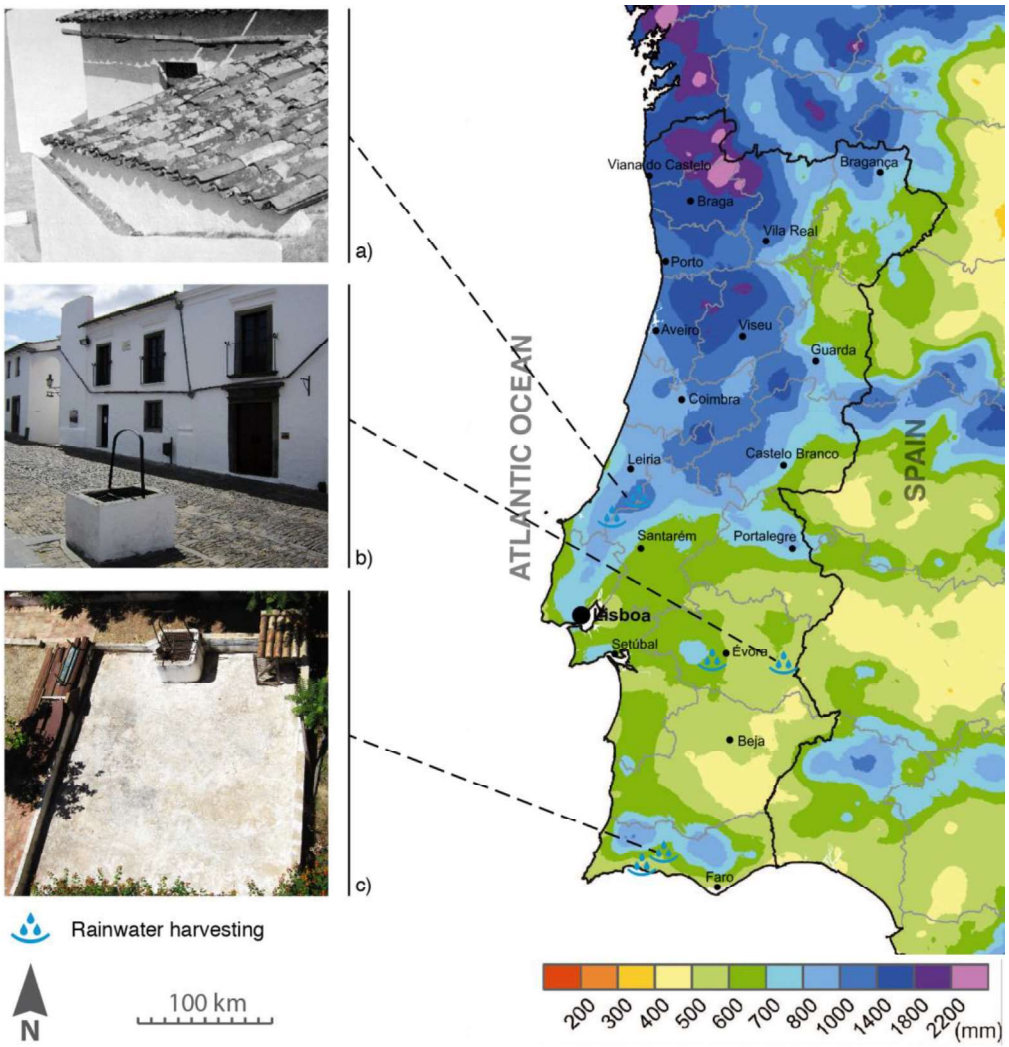

Figure 3. Map of average total annual precipitation in Portugal, showing the points where strategies for rainwater harvesting are placed. a-b) Gutter system that leads water to a cistern (image "a" source: (AAVV 1988); c) whitewashed floor for rainwater collection and cistern's access point. Map adapted from (AEMET & IM 2011)

The Estremadura mountains have the highest levels of rainfall in this region (Fig. 3) - a bit similar to what happens in the northwest, mountain acts as a barrier to the winds from the sea that bring the rain (AAVV 1988). But, ironically, due to the permeability of limestone

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soil of this zone, is where water is more scarce (AAVV 1988). To address this problem, population needed to collect rainwater in cisterns through interesting gutter systems (Fig. 3a). The water tank was an essential element of houses in this area.

The village of Monsaraz due to the fact of being on a top of a cliff has water shortages. This shortage has led to the inhabitants to provide their homes with a gutter system to collect rainwater (Fig. 3b) that was conducted into a large cistern below the castle, ensuring the provision for the whole village (AAVV 1988).

The low rainfall that occurs in most of the Algarve territory led populations to provide their houses with rainwater harvesting systems for domestic use similar to the previously mentioned. For this purpose they built gutters under the eaves, or inserted them in the walls themselves, leading the water to a cistern. When the water collected from the roof was not enough they also resort to the threshing floor to greatly increase the harvest area (Fig. 3c). The threshing floor is covered with tiles and has several slopes that conduct the water to a small hole, which communicates with the cistern, as illustrated by the example in Figure 3c. Another point worthy of note is the confinement of the threshing floor by small low walls and the abundant whitewashing of the entire ground surface to nullify the natural acidity of rainwater (AAVV 1988).

5. DISCUSSION AND CONCLUSIONS

The bioclimatic strategies found in Portuguese vernacular architecture, some of them featured in this paper, reveal a close relation with the local climate. From the examples shown it is clear the division of the country and the purpose of the main strategies according to climate. In addition, the strategies show effectiveness in mitigating the adverse effects of those climates.

Regarding the glazed-balconies found in northern Portugal, the solar orientation to the south quadrant allows them to be a privileged and effective element to capture solar gains and also to prevent heat losses. Considering the results obtained in a recent study (Fernandes, Pimenta, et al. 2015), the balconies are architectural elements that can have a positive impact on the optimization of the passive behaviour of buildings by reducing their energy needs for heating.

Thatch had been used for a long time in the north, mainly in mountainous areas with rye crops. It has the advantages of being a natural material, low cost, with a good performance against natural elements, such as rain and snow, as well as insulation properties. The latter is particularly useful to mitigate the harsh cold season. In Portugal, this technique fell into disuse, yet has good potential to be used in contemporary times, as in other countries.

From the analysis of the passive cooling strategies used in vernacular architecture located in the south, it is possible to conclude that the use of a combined set of passive strategies has an adequate response to the intense summer heat. Recent studies have demonstrated that the combination of passive cooling strategies allowed ensuring thermal comfort conditions just by passive means, without the use of any mechanical cooling system (Fernandes, Mateus, et al. 2015; Fernandes, Pimenta, et al. 2015). The adoption of such

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strategies in buildings from this region can greatly contribute to reducing energy needs for cooling and therefore to reduce energy use.

The rainwater harvest in Portuguese vernacular architecture is paradigmatic due to the numerous examples for capturing and storing water. Although the vast majority of examples were located in areas with scarce water resources, the case of Estremadura mountains is a good example of the opposite. From this example is possible to verify that beyond the climate many other factors influence the architectonic form. Currently, there are already plenty of rainwater harvesting systems developed, but the greatest potential that withdraws from the vernacular examples is the architectural integration capabilities of these systems.

Taking into consideration the results presented in this study, it can be stated that climate-responsive passive strategies used in vernacular architecture to mitigate the effects of climate, due to their simplicity and pragmatism, have significant potential to be improved and adapted to contemporary construction.

Therefore, this is an on-going research work that intends to develop more detailed and comprehensive data on vernacular strategies, in order to be useful for architects and engineers involved in the development of climate-responsive and energy-efficient buildings.

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